HEMISPHERIC SPECIALIZATION FOR PHONOLOGICAL PROCESSING

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ABSTRACT - Ear advantage as an indicator of hemispheric specialization for phonological processing was examined during a rhyme test by means of response time, accuracy and laterality index on right-handed female subjects.

INTRODUCTION

It has been widely accepted that the left cerebral hemisphere is dominant for language functions in over 90% right-handed and over 70% left-handed individuals. This is particularly true for speech production, whereas speech perception is more widely distributed and activates larger cerebral areas including the right hemisphere. It has also been shown that functional asymmetries (including language) are clearer in males than in females (Damasio and Damasio, 1992; Kimura, 1992; Kalat, 1995; Webster, 1995). Phonological processing is a segment of language functioning which has been found to be less left-lateralized than syntax, but studies of cerebral dominance have consistently shown right-ear advantage (REA) and right-visual-field advantage (RVFA), both indicating left-hemisphere dominance, on phonological tasks (Friederici et al., 1993; Praamstra and Stegeman, 1993; Frackowiak, 1994; Gordon et al., 1994; Ojemann, 1994; Fromkin, 1995; Hagoort and Brown, 1995). Although most authors agree that left cerebral hemisphere is active during phonological processing (Gordon, 1980; Molfese, 1980; Hutner and Liederman, 1991; Rayman and Zaidel, 1991; Perier et al., 1992; Pulvermuller, 1992; Kraemer and Zenhausern, 1993; Frackowiak and Turner, 1995), some disagree (Praamstra and Stegeman, 1993; Cardoso-Martins, 1994). Various versions of rhyme tests have been accepted as indicative of phonological processing (Praamstra and Stegeman, 1993; Webster, 1995). The aim of this study was to determine possible ear advantage (contralateral cerebral hemisphere dominance) for phonological processing measured by the percentage of correct responses, laterality index (LI) and response time (RT). If phonological processing is indeed mediated by the left hemisphere, and if rhyme tests are a reliable measure of hemisphere activity during that particular language function, REA should become evident as higher percentage of correct responses, high positive LI and shorter RTs to stimuli presented to the right ear as opposed to those presented to the left ear.

MATERIAL AND METHOD

The subjects were 55 female student volonteers, between 18 and 25 years of age (average: 20), right-handed according to the questionnaire about the hand used in 12 everyday activities and foot preferred in 6 functions (Mildner, 1996), with no familial sinistrality, no history of neurological disorders, with normal and symmetric hearing. All subjects were native speakers of standard Croatian.

Recording and reproduction were done on Sony MiniDisc Recorder MDS-101. Test materials were edited on a personal computer (Sound Blaster 16, Creative WaveStudio version 2.01, Windows 3.1; sampling frequency during analog-digital conversion: 11025 Hz). The apparatus and software for computer-aided RT recording and measurement were designed at the University of Zagreb. Rona Kern Type G stereophonic headphones were used. All stimuli were recorded by a male native speaker of standard Croatian. The tests were run in a quiet but not specially sound-treated room (ambient noise less than 40 dB).

The test material consisted of 24 pairs of monosyllabic words, half of which rhymed. Half of the pairs were presented to the right ear, and the other half to the left ear. This yielded 4 stimuli categories with 6 word pairs each: rhyming pairs presented to the left ear, non-rhyming pairs presented to the left ear, rhyming pairs presented to the right ear, and non-rhyming pairs presented to the right ear. The level of presentation was 75 dB. The order of stimuli presentation to left or right ear was quasi-random. The opposite ear was masked with a murmur of conversation ± 5 dB re presentation level. 300 ms

before each pair a 1000 Hz pure tone was presented simultaneously to both ears (for 250 ms) to bring the subjects' attention back to the middle.

Oral instructions were given before the test, and a practice test was run to familiarize the subjects with the procedure. The task was to answer whether the words in the pair rhymed or not. The responses were given manually, by pressing the response plate positioned on the table in the midline in front of the subject, with both hands - thumbs for a positive answer and index fingers for a negative answer. The subjects were encouraged to respond as fast as possible.

RTs (to the nearest ms) and accuracy were recorded and calculated by personal computer. SPSS package was used for statistical analysis.

RESULTS AND DISCUSSION

The average accuracy for the entire group of subjects and all stimuli was very high (95.68%). Therefore, the formula used to calculate LI was (as suggested by Bradshaw and Nettleton, 1983 for overall accuracy better than 50%)

$$LI = \frac{Rc - Lc}{Re - Le} \times 100$$

where Rc = number of correct responses to stimuli presented to the right ear; Lc = number of correct responses to stimuli presented to the left ear; Re = number of errors in responses to stimuli presented to the right ear, and Le = number of errors in responses to stimuli presented to the left ear. Obviously, positive LI indicates REA and negative LI indicates LEA, whereas the values of LI indicate the degree of laterality. Average LI obtained by such calculation was 17.56, which suggests a REA. However, that advantage is not statistically significant ($p > 0.05$) and the median is 0. Upon inspection of Figure 1, it becomes evident that the greatest number of subjects (24 or 43.64%) had LI = 0, (either 100% of correct responses or the same number of errors in responses to stimuli to either ear). REA was found in 21 (38.18%) subjects and LEA in 10 (18.18%) subjects.

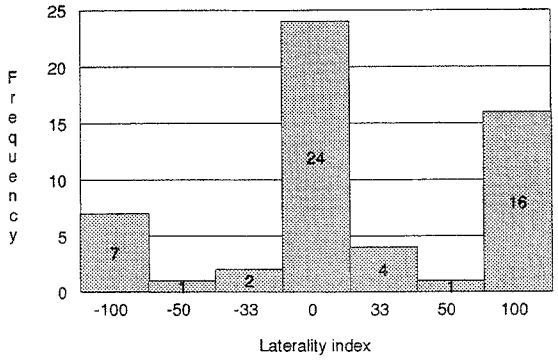

Figure 1. Laterality indices for the entire sample (N = 55)

Figure 2 illustrates the relationship between RTs and the stimulated ear (L,R) and rhyming status (rhyming, nonrhyming).

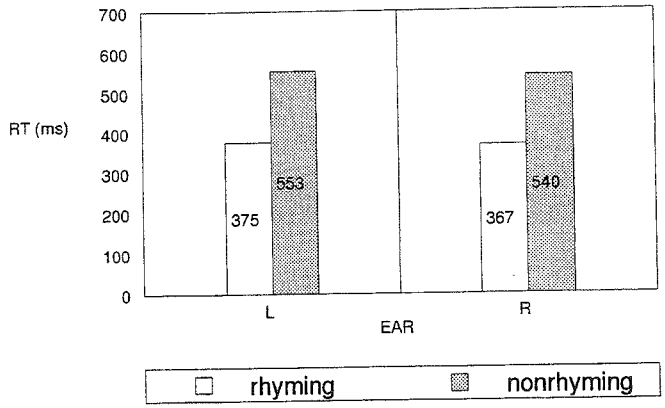

Figure 2. Response times as a function of rhyming status and stimulated ear

One-way ANOVA has shown that the stimulated ear does not affect significantly RT ($p=0.56$), but that responses are significantly faster to rhyming pairs ($p=0.00$). Two-way ANOVA with stimulated ear (L,R) and rhyming status (rhyming, nonrhyming) as independent variables, reveals the main effect of rhyming status ($p=0.00$) but not of the stimulated ear ($p=0.54$), with insignificant interaction ($p=0.87$).

Accuracy was not significantly affected by the rhyming status ($p=0.07$) or ear ($p=0.49$), but it should be stressed that the responses to rhyming stimuli are consistently more accurate than to nonrhyming pairs.

In order to examine whether there is a trade-off between accuracy and RT regression analysis was carried out. However, contrary to expectations, a negative correlation (significant: $p=0.00$, but weak: $r=-0.28$) was found: the faster the responses the higher the accuracy.

Praamstra and Stegeman (1993) found by measuring event related potentials (ERPs) that rhyming status affects the responses: nonrhyming stimuli evoked significantly greater negative deflections than the rhyming stimuli, and RTs were shorter to rhyming stimuli, as was found in this study. Levinthal and Hornung (1992) also found that RTs were longer for responses to nonrhyming words or, in general, that RTs are longer to stimuli which require a negative answer. Melamed and Zaidel (1993) reached the same conclusion. It seems that the positive rhyming status is expected, and the subjects therefore react less 'violently' and faster to such stimuli.

Gazzaniga (1994) found that the responses are more accurate to rhyming words. On the other hand, Rayman and Zaidel (1991) reported that their subjects responded more accurately to nonrhyming pairs. As mentioned above, in this study the trend to respond to rhyming stimuli more accurately only approached significance. With respect to ear advantage, Kraemer and Zenhausern (1993) reported more accurate responses on rhyme tests to stimuli presented to the right ear. In this study there was only a trend toward REA, wiht no significant difference between the ears.

There are several possible reasons for the absence of ear advantage, which are not related to the task itself: subjects' gender and test type. As mentioned in the Introduction, most studies have shown that women are less clearly lateralized than men and that perception is less clearly lateralized than production. Another reason for the absence of asymmetry in RTs and accuracy may be global processing of the stimuli, as rhythmic and musical forms for which right hemisphere activation is characteristic. Cardoso-Martins (1994) also found symmetrical responses of her subjects and concluded that rhyme detection does not necessarily involve identification of segments in presented pairs, but rather a sensitivity to some global phonological similarity. Some other authors have discussed the possibility of right hemisphere processing of rhyme (see Genesee et al., 1978 for review of earlier papers) as 'gestalts' and musical forms. Since it is possible to determine without segmentation whether the pairs of words rhyme or not, an uncontrolable contribution of the right hemisphere is possible on such tasks in two ways: (1) some subjects may change strategy during the task, switching between global and segmental, or (2) some subjects may use the segmentation strategy (left hemisphere) and the others global strategy (right hemisphere). In both cases the sample data will show no functional asymmetry. Finally, it is possible that rhyme detection as a manifestation of phonological processing is represented more symmetrically in the brain than was originally believed. This was suggested by Praamstra and Stegeman (1993) on the basis of ERP results.

CONCLUSIONS

Rhyme detection as a measure of phonological processing is equally successful and fast regardless of the stimulated ear, i.e. symmetrically represented. The absence of asymmetry in this study may be attributed to the subjects (females), nature of measurement (perception rather than production) and global (or inconsistent) processing strategy. Responses to rhyming pairs of words are significantly faster, but only insignificantly more accurate. There is no trade-off between accuracy and response times: faster responses are more accurate.

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